DETERMINATION OF BENZENE IN
COMMERCIAL GASOLINE

BY

RAYMOND K. SCHERGER

ARMOUR INSTITUTE OF TECHNOLOGY

1921

DETERMINATION OF BENZENE IN COMMERCIAL GASOLINE

A THESIS

PRESENTED BY

RAYMOND K. SCHERGER

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

CHEMICAL ENGINEERING

MAY 31, 1921

APPROVED:

J. H. McCormack
Professor of Chemical Engineering

H. M. Raymond
Dean of Engineering Studies

L. C. Monin
Dean of Cultural Studies

Table of Contents.

The object of this work is to determine to what extent toluene and the xylenes will brominate in the presence of a catalizer, and also to determine what are the ultimate compounds formed when toluene and xylene are brominated in sunlight without a catalizer. This is to be done in order to know what happens to toluene and xylene when bromination occurs in the presence of benzene, gasoline and a brom carrier.

A method for the determination of benzene in mixtures of benzene and paraffines by bromination has been worked on and found to be successful. The method, however, is to be used to determine benzene in commercial gasoline, and in the lighter distillates of petroleum. Petroleum distillates contain varying quantities of gasoline, kerosene, benzene, toluene, xylene, and a few double bond hydrocarbons.

Therefore, in order to find if the method
prescribed is applicable it is necessary to
know what will happen to these olefine hydro-
carbons when bromination takes place in
their presence.

Inasmuch as this subject has been
treated before in the thesis of Wm. Mendius
and W. T. McCauley, it will not be neces-
sary to summarize any of the previous work
done in this line except that done by Mendius
and McCauley, since their work will be used
as a basis for this thesis.

The method for the determination of
benzene in mixtures of benzene and paraf-
fine as evolved by Mendius is as follows:

> The specific gravity of the
> oil to be tested is determined and
> .1 cc. or about .1 gram of it is
> introduced into the clean and dry
> test bottle, which already contains
> the .02 gram of pure, 200 mesh iron.
> The author recommends the use of
> an ordinary ground glass stoppered
> bottle.   Just enough carbon
> bisulphide is then added to dissolve
> the oil, say about 5 cc. Enough
> normal bromine solution is added
> to furnish the bromine for the iron

(.0579 gm. Br.), and the bromine
to form the dibrombenzene
(.360 grams. Br.) assuming the
oil to be pure benzene. This is
to furnish sufficient excess of
bromine. The bottle is immediate-
ly stoppered, water sealed and
let stand for one hour at 35° C.
A blank test should be made with
every series of tests to standard-
ize the bromine solution. At the
end of one hour the flask is
cooled, the stopper removed and
washed, and an excess of potassium
iodide solution added.. The mixture
is thoroughly agitated. The free
iodine which was liberated by the
equivalent amount of bromine not
absorbed is titrated with a 1/5th
normal solution of sodium thio-
sulphate, using starch solution to
aid in the detection of the end
point, which is the final disap-
pearance of blue color. Much agita-
tion is necessary. Knowing the
standard and relationship of the
two solutions, the amount of the
bromine absorbed is calculated.
This is the difference between the
amount of bromine solution used
and the brom-equivalent of the
thiosulphate solution, times the
standard of the bromine solution.
The amount of bromine reacting
with the iron is subtrated from
this. The resulting figure is
the amount of bromine absorbed by
the benzene. This is divided by
4.094, which gives the weight of
benzene in the oil, With this
data the percentage, by weight,
of benzene in the oil can easily
be calculated.

McCauley verified the results obtained
by Mendius and found the method he used to
determine benzene in paraffines to be ac-
curate and fairly rapid.   McCauley ran
several tests on mixtures of benzene and
gasoline and found that the method gave
good results.   He also tried various brom
carriers to substitute for the iron with
the view of making the method more rapid.
The iron, however, gave the most satisfac-
tory results.   The method of procedure was
left unchanged, remaining precisely as
Mendius had planned it.

The first problem coming to mind when
dealing with commercial mixtures of gasoline,
benzene, toluene and xylene, such as we
find, in some motor fuels is, what will happen
to the toluene and xylene when treated with
bromine in exactly the same manner as the
benzene is treated in the above determination?
The bromine solution to be used for this

purpose is to be a normal solution in freshly
distilled carbon bisulphide. It is very
important that the carbon bisulphide be per-
fectly free from water and recently distilled.
The solution must be standardized about once
every two days, since its bromine value would
change considerably on standing.

To standardize the bromine solution use
a 10 cc. sample. Put it in an Erlenmeyer
flask, add water and potassium iodide solu-
tion in excess of that required to react
with the bromine present. Titrate with
1/5th normal sodium thiosulphate solution.

The N/5 thiosulphate solution is made
by dissolving 49.664 grams. of pure sodium
thiosulphate in 1000 cc. of distilled water.

To standardize the thiosulphate solu-
tion weigh out 4.903 grams of pure dry potas-
sium dichromate and dissolve in one liter of
water. A measured amount of this solution
is added to the acid solution containing about
3 grams of potassium iodide and 10 cc. cf

strong hydrochloric acid. The solution is
diluted with 500 cc. of water, for here the
color change is not from blue to colorless,
but from blue to light green. Titrate with
the prepared thiosulphate solution. From
the weight of potassium dichromate reacted
with calculate the standard of the sodium
thiosulphate solution.

The Bromination of Toluene and
Xylene   With Iron.

The bromination product of xylene
and toluene was determined by treating
1/10th cc. of the pure substance in the
same manner as benzene is treated in the
prescribed way, namely:

The specific gravity of the xylene or
toluene to be tested is determined and
1/10th cc. or about .1 gram of it is in-
troduced in a clean and dry test bottle,
which already contains .02 grams of pure
200 mesh iron. Just enough carbon bisul-
phide is then added to dissolve the oil,
say about 5 cc. Enough normal bromine solu-
tion is then added to furnish the bromine
for the iron .0579 gram Br.), and the bromine
to form dibromtoluene and xylene (toluene
requires .2808 gram bromine - xylene re-
quired .2594 grams. bromine to form the
dibrom compound.

Many samples of toluene and xylene were

run according to this procedure, the re-
sults being shown in tables 1 and 2. From
the results is it evident that the dibrom
compound is formed in both cases. The
method of taking samples and adding bromine
solution were rather poor, consequently the
results are not as accurate as they might be,
nevertheless the results are constant enough
to show that the dibrom and nothing but the
dibrom compound was formed. A number of runs
were made in the cold (temperature 15° C.),
and the bromination was found to be the same
as when the temperature was around 35° C.
The sample applies to benzene. The all im-
portant item is that absolutely no water
should be present during the bromination and,
that the carbon bisulphide used for the
bromine solution should be freshly distilled.

The conclusion drawn from these results
is that toluene and xylene will brominate to
form the dibrom compound in the presence of

an iron catalizer at ordinary temperatures,
the bromine attaching itself to the ring.
We know, from the work done by Mendius that
benzene will brominate under the same condi-
tions also to form the dibrom compounds, and
that gasoline and other single bond paraffines
will not brominate at all. Therefore, if we
have gasoline, benzene, toluene and xylene
in a mixture, and if we brominate the mixture
the toluene, benzene and xylene will all come
down as the dibrom compound and the gasoline
will not brominate at all. In this way we
can approximate the percentage of the mixture
of benzene, toluene and xylene, but in order
to know the percentage of benzene alone we
must devise a method for the determination of
xylene and toluene in the presence of benzene
and gasoline.

Without a Catalizer.

Toluene (C_6 H_5 CH_3) and xylene (C_6 H_4 CH_3 CH_3) differ from benzene (C_6 H_6) in that they have a side chain consisting of one methyl group in the first case and two methyl groups in the second. We know from our organic chemistry that when bromination takes place in the presence of a brom carrier the bromine goes on the ring and not on the side chain. We also know that if we brominate in sunlight, and in the absence of a brom carrier, the bromine will attach itself to the side chain rather than the ring. It is to be expected that, since benzene has no side chain, bromination would not take place without catalizer, and the bromination will take place in the case of toluene and xylene without a catalizer.in the presence of sunlight. Consequently numerous samples of benzene, toluene and xylene were set up for bromina-

tion in sunlight and without any iron. The
results of this test are shown in tables, 3,
4, and 5.

From the results it is plain that there
is no bromination in the case of benzene
and that the degree of bromination in the
case of toluene and xylene depends upon the
time. However, it was found that the strength
of the sunlight also affected the bromination,
therefore, we have two variables to content
with, namely, time and light. Moreover brom-
ination does not seem to stop at any definite
place. It approaches total bromination of
the side chain, but very seldom reaches it.
When the higher brome compounds are formed
they decompose easily and consequently it
is impossible to get a definite end point
during titration. For these reasons bromina-
tion in sunlight without a catalizer was
abandoned.

With Iron and Water.

It was noticed that when a few drops
of water was present bromination of benzine
with a catalizer was seriously impaired.
It was not known how water affected the
bromination of toluene and xylene, and,
therefore, several tests were made to deter-
mine this. Five CC. of water were added
to samples of benzene, toluene and xylene
along with iron and enough bromine in a
carbon bisulphide solution to form the di-
brom compound in each case. The samples were
allowed to stand in subdued light at ordinary
temperatures for about one hour. The results
as shown in tables 6, 7, and 8 were very
promising. They showed that in the case of
benzene just enough bromine was absorbed to
react with the .02 grams of iron (.0579 gms.
bromine), and that the benzene itself was
left unbrominated. The xylene required
enough bromine to satisfy the iron and to

form the tri-brom compound. The toluene
required enough bromine to react with the
iron and to form the dibrom compound.

We conclude from this that the benzene
does not brominate when water is present
even though a catalizer is there, whereas
toluene and xylene do brominate when water
and a catalizer are present to form the di-
brom and tri-brom compounds respectively.
Inasmuch as we may not know the amounts of
xylene and toluene present and have no way
of finding out it will be necessary to average
the amount of bromine needed to brominate
equal amounts of toluene and xylene, and thus
treat the two as one compound, a gram. of
which will require .3995 grams. bromine.

> 1 gm. xylene requires 4.515 gm. br. to
> form the tri-brom compound.
>
> 1 gm. toluene requires 3.476 gms. Br.
> to form the dibrom compound.
>
> 1/2 gm. toluene plus 1/2 gm. xylene re-
> requires 3.995 gms. bromide to brominate
> the mixture.

The best results are obtained when an
excess of bromine is present and the time
is about one and one-half hours. It is only
necessary to add a small amount of water, ap-
proximately 5 cc. The time did not permit
to investigate whether or not the bromine at-
tached itself to the side chain or to the
neucules, but nevertheless in all cases a
definite compound was formed and not a mix-
ture of compounds as when the toluene and
xylene were brominated in sunlight free
from water.

CONCLUSION.

The method for the determination of
benzene in mixtures of benzene, gasoline,
toluene and xylene will require two separate
determinations, first the determination of
toluene and xylene, second the determination
of toluene, xylene and benzene. It is as
follows:

The specific gravity of the oil to be
tested is determined in 1/10th cc. or about
1/10th gram of it is introduced into a
clean ground glass stoppered bottle, which
already contains .02 grams of 20 0 mesh C.P.
iron enough normal bromine solution is added
to furnish the bromine for the iron (.0579
grams Br.), and the bromine to brominate
the oil (.4515 grams Br.), assuming the oil
to be pure toluene since toluene requires
the most bromine to be satisfied. This is to
furnish sufficient excess of bromine. In-
troduce about 5 cc. of water into the bottle,

stopper it and allow it to stand in sub-
dued light for one and one-half hours. A
blank test should be made every series of
test to standardize the bromine solution. At
the end of one and one-half hours the stopper
is removed and washed, and an excess of potas-
sium iodide solution is added. The mixture
is thoroughly agitated. The free iodine
which was liberated by the equivalent amount
of bromine not absorbed, is titrated with
1/5th normal solution of sodium thiosulphate,
using starch solution to aid the detection
of the end point, which is the final disap-
pearance of blue color. Much agitation is
necessary. Knowing the standard and re-
lationship of the two solutions the amount
or bromine absorbed is calculated. The dif-
ference between the amount of solution added
and the brom equivalent of the thiosulphate
solution times the standard of the bromine
solution gives the amount of bromine ab-
sorbed. The grams of bromine reacting with

the iron is subtracted from this. The final
result will be the amount of bromine neces-
sary to react with the toluene and xylene
present. To get the weight of a mixture of
toluene and xylene in the oil, divide the
grams of bromine by 3.995. From this result
knowing the weight of the sample the per-
centage of the mixture of toluene and xylene
is calculated.

To find the amount of benzene in the
oil go through the analysis as prescribed
by Mendius. Subtract from the final amount
of bromine necessary to brominate the oil,
the amount of bromine used in the above deter-
mination and divide the result by 4.094.

This will give the weight of benzene
in the oil. From this and the weight of the
sample the percentage of benzene is easily
calculated.

In pure mixtures of toluene and
xylene are brominated with water and a cat-
alizer according to the method prescribed,
a certain bromine absorbtion will take place.
The gram value of this absorbtion will be
greater in the case of xylene than in the
case of toluene, since a unit weight of
xylene absorbs more bromine than a unit weight
of toluene in the ratio of .4515 to .3476.
This means that one gram of pure xylene will
absorb 4.515 grams. of Br. and that one
gram of pure toluene will absorb 3.476 grams
of Br. One gram samples of all mixtures
of the two will absorb a definite amount of
bromine the value of which will lie between
4.515 and 3.476. Therefore, it is possible
to make a table or to draw a curve which will
give percentages of toluene and xylene from
the bromine value of a certain sample. Such
a table and curve is included herein.

TABLES.

TABLE I.

Bromination of Xylene with iron catalizer.

Sample	Br Absorbed	Bromine necessary for dibrom comp.	% Error
1	.2673	.2594	3.0
2	.2920	"	8.2
3	.2689	"	3.2
4	.2502	"	1.2
5	.2600	"	2.9
6	.2730	"	5.0
7	.2589	"	.0

TABLE II

Bromination of Toluene with iron catalizer.

Sample	Br. absorbed	Bromine necessary for dibrom comp.	% Error
1	.3203	.2808	13.0
2	.3109	"	10.4
3	.3129	"	11.3
4	.3030	"	7.0
5	.2912	"	3.0
6	.2943	"	3.3
7	.3021	"	6.9
8	.2734	"	6.0
9	.3043	"	7.2

TABLE III.

Benzene, Without Iron, In Sunlight.

Sample	Gr. Benzene	Br. Bromine Present	Gr. Bromine Absorbed
1	.0850	.4860	.0200
2	"	"	.0030
3	"	"	.0096
4	"	"	.0011
5	"	"	.0009
6	"	"	.0010
7	"	"	.0008
8	"	"	.0083

TABLE IV.

Toluene, In Sunlight, Without Iron.

Sample	Grms.Toluene	Gr. Br. Present	Gr. Br. Abs.	Time
1	.08647	.4860	.0320	5
2	"	"	.0560	10
3	"	"	.0920	15
4	"	"	.0930	20
5	"	"	.1240	20
6	"	"	.1120	30
7	"	"	.1630	30
8	"	"	.2640	60
9	"	"	.3242	2 hr.
10	"	"	.4326	3 hr.

TABLE V.

Xylene, Without Iron, In Sunlight.

Sample	Gms. Xylene	Gr. Bromine Present	Gr. Br. Abs.	Time
1	.08589	.4860	.0832	10 min.
2	"	.4860	.0993	15 "
3	"	.4860	.1297	20 "
4	"	.4860	.1340	20 "
5	"	.4860	.1302	20 " "
6	"	.4860	.1920	20 "
7	"	.4860	.2232	30 "
8	"	.4860	.2920	40 "
9	"	.4860	.3212	60 "
10	"	.7530	.6520	2 Hr.
11	" "	.7530	.5320	4 "
12	"	.7530	.6102	4 "

TABLE VI.

Bromination of benzene in present of water
and iron.

Sample	Gm. Benzene	Gm. Br. Present	Total Gm. Br.	By iron	Abs. By Benzene
1	.08500	.4860	.0580	.0579	.0001
2	"	"	.0592	. "	.0013
3	"	"	.0590	"	.0001
4	"	"	.0593	"	.0001
5	"	"	.0620	"	.0015
6	"	"	.0540	" "	.0000
7	"	"	.0572	"	.0000
8	"	"	.0593	"	.0014
9	"	"	.0584	"	.0005
10	"	"	.0572	"	.0000

TABLE VII

Bromination of Toluene in presence of
water and iron.

Sample	Gm. Toluene	Gm.Br. Present	Gm.Br req.	Gm. Br. Abs.	% Error
1	.1000	.4860	.3476	.3320	5.0
2	"	"	"	.3360	3.0
3	"	"	"	.3420	.91
4	"	"	"	.3224	7.0
5	"	"	"	.3446	.72
6	"	"	"	.3390	2.9
7	"	"	"	.3424	.89
8	"	"	"	.3296	6.6
9	"	"	"	.3420	.91
10	"	"	"	.3417	.90

TABLE VIII

Bromination of Xylene in presence of
water and iron.

| Smple	Gm. xylene	Gm.Br. Present	Gm. Br. req.	Gm. Br. Abs.	% Error.
1	.1000	.4860	.4515	.4002	-11.2
2	"	"	"	.4012	-11.0
3	"	"	"	.4423	.2
4	"	"	"	.3920	-13.5
5	"	"	"	.4230	-6.2
6	"	"	"	.4360	-3.1
7	"	"	"	.4200	-6.7
8	"	"	"	.4195	-8.5
9	"	"	"	.4093	-10.8
10	"	"	"	.4162	-8.7

TABLE IX

For pure mixtures of Toluene and Xylene.

. 1 gm. sample of mixture.

Gm. Toluene	Gm. Xylene	Gm. Br.	% Toluene	% Xylene
.10	.00	.3476	100	0
.09	.01	.3479	90	10
.08	.02	.3683	80	20
.07	.03	.3787	70	30
.06	.04	.3891	60	40
.05	.05	.3995	50	50
.04	.06	.4099	40	60
.03	.07	.4213	30	70
.02	.08	.4307	20	80
.01	.09	.4411	10	90
.00	.10	.4515	0	100

Graph showing the percentages of Toluene
and Xylene from Bromine values.

% Tol.   % Xyl.

Gm. Br.
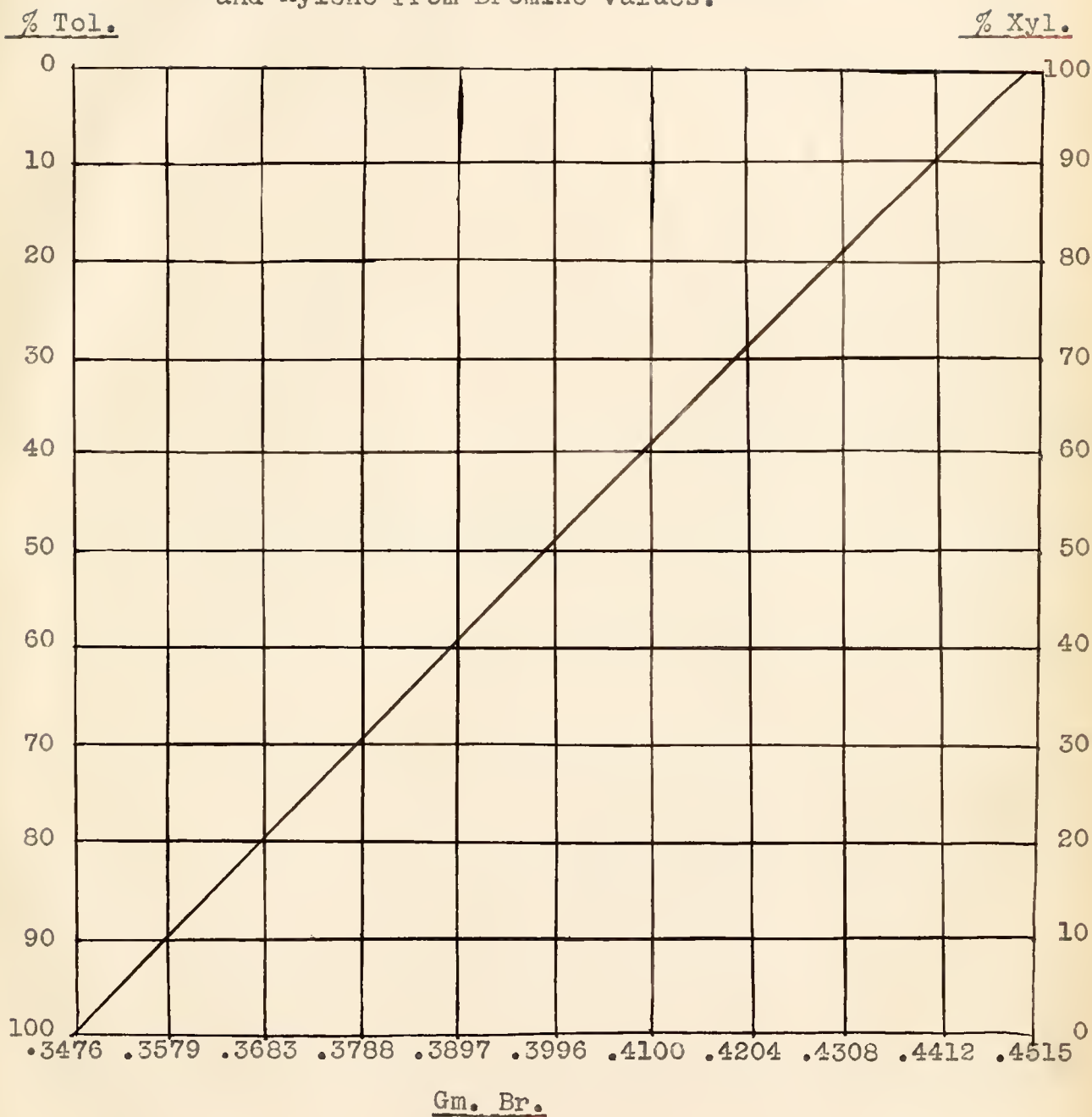
BIBLIOGRAPHY

Barker. J. T. - Experimentelle Bestimmung
    und thermodynamische Berechnung der
    Damfdrucke von Toluol, Naphthalin, und
    Benzol. Ztschr. phys. Chem., Bd. 71,
    1919, pp. 253-254.
    Determination by means of vapor pressures
    and values compared with those calculated
    from Nernst's theory.

Burrell, G.A., and Robertson, I.W. The deter-
    mination of benzol in gas mixtures. Jour-
    Ind. Eng.Chem., vol. 7, August, 1915,
    pp. 669-670. The percentage of benzol was
    checked by combustion analysis and it was
    found that all the benzol was separated
    at -78°.

------- The separation of the illuminants in
    mixed coal and water gas. Jour. Ind. Eng.
    Chem., vol. 7, Jan. 1915. pp. 17-21. The
    gas free from water, is cooled in a
    liquefaction bulb to -78°C. and as much gas
    as possible removed with a pump. The
    condensed liquid is then vaporized and its
    pressure compared to the original pressure
    gives the percentage of benzene.

Edwards. A. The estimation of benzene and
    toluene in commercial mixtures. J. Soc.
    Chen. Ind. vol. 35, pp. 587-590. (1916).
    Depends on the isolation of the con-
    stituents of naphtha in pairs by frac-
    tional distillation and the measurement
    of the b.p. of the mixture and the
    determination of the percent composition
    by reference to a boiling point composition
    curve constructed from a study of known
    mixtures.

Davis. G.E. On the valuation of the crude
    naphthas of commerce. J. Soc. Chem. Ind.,
    vol. 4, Nov. 30, 1885. pp. 645-649. A
    lengthy discussion involving the dis-
    tillation and determination of benzol,
    toluol, and xylene.

Dieterich, Karl. Analysis and valuation of
    motor fuels; fourteen methods for ex-
    amining them. Automobile. vol. 33,
    July 29, Aug. 5, 1915. pp. 202-205,
-   247-249, 267. Properties of benzol and
    gas are described. Described numerous
    methods of testing.

Frank, Fritz. Commercial Benzol. Gas World,
    vol. 36, 1902, pp. 182-184; Jour. Gas
    Lighting Vol. 78, Aug. 6, 1901. pp. 341-
    342. Gives a review of the history of
    benzol, describing uses and tests.

-----Der Handelsverkehr mit Benzolen, ihre
    Zusammensetzung, Untersuchung und Ver-
    werthung Chem. Ind., Jahrg 24, Apr. 15,
    May 1, 1901, pp. 237-241, 262-266. Gives
    review of the early history of benzol
    industry and literature, also analytical
    methods.

Grual, C.L.O. Determining the amount of benzene
    in gas. U.S. 1,163,654. A continuous
    method for the determination of benzene in
    gas as produced.

Heusler, F. Beitrage zer Chemie des Braunkohlen-
    theers. Ber. Duet. cem. Gasell., Jahrg.25,
    Bd. 2,1892, pp. 1665-1678; 28, Bd.1, 1895,
    pp.488-498. Benzene and toluene are es-
    timated by formation of dinitro bodies.

James. H.W. Determination of toluene, application to benzene and xylene. J. Soc. Chem. Ind. vol. 35, pp.236-240 (1916). Method consists of dividing the total distillate into two parts, one being a mixture of benzene and toluene, the other toluene and xylene. These fractions are in turn very accurately fractionated under carefully regulated conditions. The percent toluene is determined by measurement of volumes.

Karpiuski. A. Control over the output of aromatic hydrocarbons. Petroleum Rev. vol. 37, pp. 108; 205-206. (1917). Paper includes method for determination of benzene by use of refractometer.

Krieger. A._ Benzolbestimmung im Gase. Jour. Gasbel., Jahrg. 58, Feb. 6, 1915, pp. 61-64; Chem. Abs., vol. 8, Aug. 10, 1915, pp 2141-2142. Am. Gas. Light Jour., vol. 102, 1915, pp. 299-300; Jour. Gas Lighting, vol. 129, 1915, p. 450. J. Soc. Chem. Ind., vol. 34, Mar. 31, 1915, p. 266. Summarizes previous work on determination of benzol. Author modifies Mueller's method of gas washing and improves apparatus. Details of method are given.

Lunge, Georg. Coal tar and ammonia, 1919. Has chapter entitled "Benzene - physical and chemical properties" (pp 177-183) which has a valuable list of references.

Lunge, Georg., and Berl. Ernest, Chemiscj-technische Untersuchungsmethoden. Berlin 1911, Bd. 3. Gives detailed method for determination of benzene by dinitro method; also many references to the literature.

Northall-Laurie, D. A new method for the
    determination of toluene in commercial
    toluols. Analyst, vol. 40, Sept. 1915,
    pp. 384-389. Charts are prepared giving
    the boiling points of various mixtures
    of benzene and toluene, toluene and
    xylene. Percentage composition is deter-
    mined by reference to these curves. This
    method is applicable to benzene.

Reineke, J.H. Determining the benzene con-
    tent of gases. Ger. 285, 920.

Rothkopf. B.P. Estimation of benzene and
    toluene in coal gas, Gas World. vol.66,
    p. 406, 1917.

Shuttleworth, L. Benzene absorption oils in
    practice and analysis. Gas World Vol.
    67, No. 1728 (Coking and By-Products
    Section) 11 (1917).

Speer, F.W. andKohr, A.A. Estimation of
    benzene and toluene in light oils. Gas
    world vol. 67. pp. 146-147. (1917).

Spielmann. P.E. and Wheeler, E.G. The
    analysis of commercial benzol. J. Soc.
    Chem. Ind. vol. 35, pp. 396-399, (1916).
    Determination of toluene, carbon di-
    sulfide, paraffins, is made by use of
    curves involving density, boiling point,,
    and volume. Benzene is determined by
    difference.

Spielmann, P.E. and Petrie, G.C. Crude benzole.
    J.Soc.Chem.Ind. vol.36, pp. 831-836,(1917).

Thorpe, Edward. Dictionary of applied chem-'
    istry; benzene, vol. 1, 1912; pp. 439-
    447. Gives a survey of the physical and
    chemical properties of benzene, with
    methods of preparation, purification and
    nitration.

Wilson, D. and Roberts, L. Determining
    benzene, toluene, and solvent naphtha in
    light oils. .J. Gas Lighting, vol. 134,
    pp. 225-227. (1916).

Whiton, L. The determination of benzene in
    coke oven gas by Burrell's vapor apparatus.
    J. Ind. Eng, Chem. vol. 8, pp. 733-734.
    (1916).

------- Commercial benzol in the United States.
    J. Ind. Eng. Chem., vol. 3, Jan. 1911.
    pp. 10-13. Gives a brief description of
    uses and manufacture of benzene, including
    commercial tests.

-------The estimation of benzol. J. Gas
    Lighting. vol. 131, July 27, 1915. p. 180.

Anonymous. Estimation of benzol in gas. Gas
    Jour. vol. 140. p. 220. (1917).